Diameter-controlled Growth of Single-walled Carbon Nanotubes by Using Nano-Diamonds

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Structure control (diameter, length and chirality) is still one of the challenging topics in the research of single-walled carbon nanotube (SWNT) growth, and the chirality control is the most important and difficult among them. Because the variety of chirality is limited for the small diameter SWNTs, the SWNT growth with smaller diameter attract attention. Here, we perform CVD growth by using nano-diamond particles as the catalyst [1] and investigate the CVD condition dependence of SWNT tube diameter.

The average diameter of the as-received nano-diamond particles is approximately 4 nm, which was measured by atomic force microscope. In order to decrease the diameter, the nano-diamond particles were heated (oxidized) in air (600 to 900 degree C) on silicon substrates. After the 600 degree C oxidization, the average diameter and dispersion were 1.5 and 0.3 nm, respectively. Increasing the oxidization temperature, the average diameter gradually decreased. CVD growth was performed with ethanol vapor as the carbon source.

The CVD temperature dependence of the tube diameter was analysis by using RBM peaks. Taking consideration with resonant Raman effects [2] and the chirality dependence of the RBM peak intensity [3], the tube diameter distribution was estimated. The average tube diameter was 1.1, 1.3 and 1.4 nm for 700, 800 and 900 degree C, respectively. Since diamond structure is quite stable, it is not possible to change the diameter or structure in the CVD process, unlike metal nano-particles. The temperature dependence obtained here clearly shows that smaller diameter SWNTs grow preferentially over larger diameter SWNTs. Combining nano-diamond particles with smaller diameter and lower CVD temperature decrease SWNT diameter, precisely.

[1] D. Takagi, Y. Kobayashi and Y. Homma, J. Am. Chem. Soc. 131 (2009) 6922.
[2] C. Fantini, et al., Phys. Rev. Lett., 93 (2004) 147406.
[3] K. Sato, et al., Chem. Phys. Lett., 497 (2010) 94.